

6 the optical disk apparatus further comprising:
7 connecting means for connecting the rotating apparatus and the moving
8 apparatus with an electric source to supply an electric power to the rotating
9 apparatus and the moving apparatus;
10 actuating means for actuating the compound objective lens of the optical
11 head apparatus;
12 focus control means for controlling the actuating means to perform a
13 first focus control of the optical head apparatus corresponding to the thickness
14 T1 of the first information medium and a second focus control of the optical
15 head apparatus corresponding to the thickness T2 of the second information
16 medium according to the focus error signal read by the optical head apparatus;
17 tracking control means for controlling the actuating means to perform a
18 first tracking control of the optical head apparatus corresponding to the
19 thickness T1 of the first information medium and a second tracking control of
20 the optical head apparatus corresponding to the thickness T2 of the second
21 information medium according to the tracking error signal read by the optical
22 head apparatus;
23 detecting means for detecting whether the optical disk has the first
24 information medium having the thickness T1 or the second information
25 medium having the thickness T2; and
26 changing means for switching from the second focus and tracking
27 controls performed by the focus control means and the tracking control means

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28 to the first focus and tracking controls performed by the focus control means
29 and the tracking control means according to the detection of the detecting
30 means.

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1 92 (Amended). An optical disk apparatus according to claim 159, in
2 which the optical head apparatus is configured, through the compound
3 objective lens, to read an information signal, a focus error signal and a tracking
4 error signal from the optical disk rotated by the rotating apparatus;
5 the optical disk apparatus further comprising:
6 connecting means for connecting the rotating apparatus and the moving
7 apparatus with an electric source to supply an electric power to the rotating
8 apparatus and the moving apparatus;
9 actuating means for actuating the compound objective lens of the optical
10 head apparatus;
11 focus control means for controlling the actuating means to perform a
12 first focus control of the optical head apparatus corresponding to the thickness
13 T1 of the first information medium and a second focus control of the optical
14 head apparatus corresponding to the thickness T2 of the second information
15 medium according to the focus error signal read by the optical head apparatus;
16 and
17 tracking control means for controlling the actuating means to perform a
18 first tracking control of the optical head apparatus corresponding to the

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19 thickness T1 of the first information medium and a second tracking control of
20 the optical head apparatus corresponding to the thickness T2 of the second
21 information medium according to the tracking error signal read by the optical
22 head apparatus.

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1 93 (Amended). An optical disk apparatus according to claim 92 in which
2 the compound objective lens of the optical head apparatus is moved in a
3 direction to the optical disk by the moving apparatus, and the compound
4 objective lens of the optical head apparatus is operated to focus the light beam
5 on the first or second information medium by the actuating means under the
6 control of the focus control means to decrease an intensity of the focus error
7 signal to zero in case where the intensity of the focus error signal exceeds a
8 threshold.

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1 113 (Amended). An optical head apparatus according to claim 156,
2 comprising:
3 a photo detector for detecting the light beam, which is converged at an
4 information recording plane, serving as the information plane, of the first
5 information medium having the thickness T1 and at an information recording
6 plane, serving as the information plane, of the second information medium
7 having the thickness T2 by the compound objective lens and is reflected by the
8 first information medium and the second information medium, respectively, to

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9 obtain first information recorded in the information recording plane of the first
10 information medium and second information recorded in the information
11 recording plane of the second information medium.

1 115 (Amended). An optical disk apparatus according to claim 159,

2 comprising:

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3 a photo detector for detecting the light beam which is converged at an
4 information recording plane, serving as the information plane, of the first
5 information medium having the thickness T1 and at an information recording
6 plane, serving as the information plane, of the second information plane having
7 the thickness T2 by the compound objective lens and is reflected by the first
8 information medium and the second information medium, respectively;

9 focus control means for performing a first focus control of the optical
10 head apparatus corresponding to the thickness T1 of the and a second focus
11 control of the optical head apparatus corresponding to the thickness T2
12 according to the light beam detected by the photo detector;

13 tracking control means for performing a first tracking control of the
14 optical head apparatus corresponding to the thickness T1 and a second
15 tracking control of the optical head apparatus corresponding to the thickness
16 T2 according to the light beam detected by the photo detector; and

17 information detecting means for judging according to the light beam
18 detected by the photo detector, for which the first focus control and the second

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19 focus control and the first tracking control and the second tracking control are
20 performed, whether the light beam radiated from the light source is converged
21 at the information recording plane of the first information medium having the
22 thickness T1 or at the information recording plane of the second information
23 medium having the thickness T2, reproducing first information recorded in the
24 information recording plane of the first information medium from the light
25 beam detected by the photo detector in cases where it is judged that the light
26 beam is converged at the information recording plane of the first information
27 medium, and reproducing second information recorded in the information
28 recording plane of the second information medium from the light beam
29 detected by the photo detector in cases where it is judged that the light beam is
30 converged at the information recording plane of the second information
31 medium.

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1 122 (Amended). An optical disk apparatus according to claim 159,
2 in which the plurality of regions of the compound objective lens include:
3 a third region which corresponds to a numerical aperture NA3 satisfying
4 a relationship of $NA2 \leq NA3 < NA1$ and is unified with the first region of the
5 objective lens through a discontinuous plane,
6 the optical head apparatus further comprising:
7 a photo detector for detecting the light beam which is converged at an
8 information recording plane, serving as the information plane, of the first

9 information medium having the thickness T1 and at an information recording
10 plane, serving as the information plane, of the second information medium
11 having the thickness T2 by the compound objective lens and is reflected
12 therefrom, respectively;

13 focus control means for performing a first focus control of the optical
14 head apparatus corresponding to the thickness T1 and a second focus control
15 of the optical head apparatus corresponding to the thickness T2 according to
16 the light beam detected by the photo detector;

17 tracking control means for performing a first tracking control of the
18 optical head apparatus corresponding to the thickness T1 and a second
19 tracking control of the optical head apparatus corresponding to the thickness
20 T2 according to the light beam detected by the photo detector; and

21 information detecting means for judging according to the light beam
22 detected by the photo detector, for which the first focus control and the second
23 focus control and the first tracking control and the second tracking control are
24 performed, whether the light beam radiated from the optical source is
25 converged at the information recording plane of the first or second information
26 medium having either of the thickness T1 or T2, reproducing first information
27 recorded in the information recording plane of the first information medium
28 having the thickness T1 from the light beam detected by the photo detector in
29 cases where it is judged that the light beam is converged at the information
30 recording plane of the first information medium, and reproducing second

31 information recorded in the information recording plane of the second
32 information medium having the thickness T2 from the light beam detected by
33 the photo detector in cases where it is judged that the light beam is converged
34 at the information recording plane of the second information medium.

1 123 (Amended). An optical head apparatus according to claim 156,
2 in which the compound objective lens comprises
3 an optical device for minimizing an aberration occurring in the light
4 beam in cases where the light beam passing through the optical device
5 transmits through the first layer of the first information medium having the
6 thickness T1 and is focused on an information recording plane, serving as the
7 information plane, of the first information medium, and
8 a ring-shaped band, placed on at least one surface of the optical device,
9 for shifting a phase of the light beam passing through the optical device to
10 reduce a wavefront aberration caused by a difference between the thicknesses
11 T1 and T2 of the first and second information media in cases where the light
12 beam passing through the optical device transmits through the second layer of
13 the second information medium having the thickness T2 and is focused on an
14 information recording plane, serving as the information plane, of the second
15 information medium;
16 the optical head apparatus further comprising

17 a photo detector for detecting the light beam which is converged on the
18 information recording plane of the first information medium having the
19 thickness T1 and on the information recording plane of the second information
20 medium having the thickness T2 by the compound objective lens and is
21 reflected by the first information medium and second information medium to
22 reproduce information recorded in the first and second information media,
23 respectively.

1 126 (Amended). An optical head apparatus according to claim 156, in
2 which the compound objective lens comprises
3 a phase adjusting device, formed in a ring-band shape, for shifting a part
4 of the light beam radiated from the optical source,
5 the compound objective lens having a light converging performance so as
6 to converge the light beam radiated from the optical source on an information
7 recording plane, serving as the information plane, of the first information
8 medium having the thickness T1 through the layer thereof at a diffraction limit,
9 to converge the light beam, of which the part is shifted by the phase adjusting
10 device, on an information recording plane, serving as the information plane, of
11 the second information medium having the thickness T2 or the information
12 recording plane of the first information medium having the thickness T1
13 through the layer thereof,
14 the optical head apparatus further comprises

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15 a photo detector for detecting the light beam, which is converged on the
16 information recording plane of the first and second information media each
17 having the thickness T1 or T2 by the compound objective lens and is reflected
18 by the first and second information media, respectively, to reproduce
19 information recorded in the first and second information media, respectively.

1 128 (Amended). An optical disk apparatus according to claim 159, in
2 which the optical head apparatus comprises

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3 an optical device for minimizing an aberration occurring in the light
4 beam in cases where the light beam passing through the optical device
5 transmits through the layer of the first information medium having the
6 thickness T1 and is focused on an information recording plane, serving as the
7 information plane, of the first information medium,

8 a ring-shaped band, placed on at least one surface of the optical device,
9 for shifting a phase of the light beam passing through the optical device to
10 reduce a wavefront aberration caused by a difference between the thicknesses
11 T1 and T2 of the first and second information media in cases where the light
12 beam passing through the optical device transmits through the layer of the
13 second information medium having the thickness T2 and is focused on the
14 information recording plane thereof, and

15 a photo detector for detecting the light beam, which is converged on the
16 information recording planes of the first and second information media having

17 the thicknesses T1 and T2 by the compound objective lens and is reflected by
18 the first and second information media, respectively, to reproduce information
19 recorded in the first and second information media, respectively;

20 focus control means for performing a first focus control of the optical
21 head apparatus corresponding to the thickness T1 of the first information
22 medium and a second focus control of the optical head apparatus
23 corresponding to the thickness T2 of the second information medium according
24 to the light beam detected by the photo detector;

25 tracking control mans for performing a first tracking control of the
26 optical head apparatus corresponding to the thickness T1 and a second
27 tracking control of the optical head apparatus corresponding to the thickness
28 T2 according to the light beam detected by the photo detector; and

29 information detecting means for judging according to the light beam
30 detected by the photo detector, for which the first focus control and the second
31 focus control and the first tracking control and the second tracking control are
32 performed, whether the light beam radiated from the optical source is
33 converged at an information recording plane, serving as the information plane,
34 of the first or second information medium having the thickness T1 or T2,
35 reproducing first information recorded in the information recording plane of the
36 first information medium having the thickness T1 from the light beam detected
37 by the photo detector in cases where it is judged that the light beam is
38 converged at the information recording plane of the first information medium,

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39 and reproducing second information recorded in the information recording
40 plane of the second information medium having the thickness T2 from the light
41 beam detected by the photo detector in cases where it is judged that the light
42 beam is converged at the information recording plane of the second information
43 medium.

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1 131 (Amended). An optical head apparatus according to claim 156, in
2 which the plurality of regions of the compound objective lens include
3 a third region, corresponding to a numerical aperture NA4 equal to or
4 lower than the numerical aperture NA2 ($NA4 \leq NA2$), for changing the light beam
5 radiated from the optical source to converge the light beam on an information
6 recording plane, serving as the information plane, of the second information
7 medium having the thickness T2 through the layer thereof; and
8 a photo detector for detecting the beam light, which is converged on the
9 information recording plane of the first information medium having the
10 thickness T1 and on an information recording plane, serving as the information
11 plane, of the second information medium having the thickness T2 by the
12 compound objective lens and is reflected by the first and second information
13 media having the thickness T1 and T2, respectively, to reproduce first
14 information recorded in the first information medium and second information
15 recorded in the second information medium, respectively.

1 132 (Amended). An optical disk apparatus according to claim 159, in
2 which the plurality of regions of the compound objective lens include
3 a third region, corresponding to a numerical aperture NA4 equal to or
4 lower than the numerical aperture NA2 ($NA4 \leq NA2$), for changing the light beam
5 radiated from the optical source to converge the light beam on an information
6 recording plane, serving as the information plane, of the second information
7 medium having the thickness T2 through the layer thereof;
8 a photo detector for detecting the light beam, which is converged on the
9 information recording plane of the first and second information media each
10 having the thickness T1 or T2 by the compound objective lens and is reflected
11 by the first and second information media, respectively, to reproduce
12 information recorded in the first and second information media, respectively;
13 focus control means for performing a first focus control of the optical
14 head apparatus corresponding to the thickness T1 of the first information
15 medium and a second focus control of the optical head apparatus
16 corresponding to the thickness T2 of the second information medium according
17 to the light beam detected by the photo detector;
18 tracking control means for performing a first tracking control of the
19 optical head apparatus corresponding to the thickness T1 of the first
20 information medium and a second tracking control of the optical head
21 apparatus corresponding to the thickness T2 of the second information
22 medium according to the light beam detected by the photo detector; and

23 information detecting means for judging according to the light beam
24 detected by the photo detector, for which the first focus control and the second
25 focus control and the first tracking control and the second tracking control are
26 performed, whether the light beam radiated from the optical source is
27 converged at an information recording plane, serving as the information plane,
28 of the first information medium having the thickness T1 or at an information
29 recording plane, serving as the information plane, of the second information
30 medium having the thickness T2, reproducing first information recorded in the
31 information recording plane of the first information medium from the light
32 beam detected by the photo detector in cases where it is judged that the light
33 beam is converged at the information recording plane of the first information
34 medium, and reproducing second information recorded in the information
35 recording plane of the second information medium from the light beam
36 detected by the photo detector in cases where it is judged that the light beam is
37 converged at the information recording plane of the second information
38 medium.

1 133 (New). A compound objective lens, comprising a region to produce a
2 focal point on an information plane through a layer, wherein
3 the region of the lens is divided into a plurality of regions including at
4 least both of a first region and a second region by dividing the region of the lens
5 depending on differences in a distance from an optical axis of the lens,

6 the first region being located farther from the optical axis than a position
7 of the second region,

8 the second region being optimized so that the lens has a numerical
9 aperture NA2 to produce a focal point through a second layer on an
10 information plane placed at a distance T2 from the surface of the second layer,
11 and

12 both of the first region and the second region being optimized so that the
13 lens has a numerical aperture NA1 (NA1 is not equal to NA2) to produce a focal
14 point through a first layer on an information plane placed at a distance T1 (T1
15 is not equal to T2) from the surface of the first layer.

134 (New). A compound objective lens according to claim 133, wherein
the second region has an optical relief,

the numerical aperture NA1 is larger than the numerical aperture NA2,
and

the distance T1 is smaller than the distance T2.

135 (New). A compound objective lens according to claim 134, in which
the optical relief is formed concentrically in the second region of the compound
objective lens.

136 (New). A compound objective lens according to claim 134, in which the optical relief is provided on a side of the compound objective lens opposite to the optical disk.

137 (New). A compound objective lens according to claim 134, in which the first region has an optical relief formed therein.

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138 (New). A compound objective lens according to claim 137, in which the optical relief of the first region is higher in height than the optical relief of the second region.

139 (New). A compound objective lens according to claim 134, comprising an objective lens on which the plurality of regions are provided.

140 (New). A compound objective lens according to claim 134, comprising an objective lens and a relief lens on which the plurality of regions are provided.

141 (New). A compound objective lens according to claim 134, in which the distance T1 is larger than 0.4 millimeter and smaller than 0.8 millimeter.

142 (New). A compound objective lens according to claim 134, in which the optical relief of the second region is a hologram.

143 (New). A compound objective lens according to claim 142, in which the hologram of the second region has a diffraction efficiency lower than 100%.

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144 (New). A compound objective lens according to claim 142, in which the hologram of the second region is formed to function as a convex lens.

145 (New). A compound objective lens according to claim 142, in which the hologram of the second region has slopes inclining to the same direction as a surface of a convex lens.

146 (New). A compound objective lens according to claim 142, in which the plurality of regions include at least one region having no optical hologram.

147 (New). A compound objective lens according to claim 146, in which the first region has no hologram.

148 (New). A compound objective lens according to claim 142, in which the first region has a hologram.

149 (New). A compound objective lens according to claim 148, in which the first region is higher in a diffraction efficiency than the second region.

1 150 (New). A compound objective lens according to claim 134, in which
2 a height H of the optical relief formed in the second region is set to:

3
$$H < \lambda / (n(\lambda) - 1),$$

4 where a symbol λ denotes a wavelength of a light beam passing through the
5 second region and a symbol $n(\lambda)$ denotes a refractive index of a material of the
6 optical relief at the wavelength λ of the light beam.

151 (New). A compound objective lens according to claim 150, in which a difference in phase modulation degree of the light beam passing through the second region is lower than 2π radian.

152 (New). A compound objective lens according to claim 142, in which the hologram of the second region is formed into a blazed hologram lens.

153 (New). A compound objective lens according to claim 152, in which the hologram is formed into saw-teeth in a section thereof.

1 154 (New). An optical head apparatus for performing at least one of
2 recording and reproduction of pieces of information on and from an optical disk
3 placed to face the optical head apparatus, comprising

4 (i) an optical source for radiating a light beam; and

5 (ii) a compound objective lens receiving the light beam and comprising a
6 region to produce a focal point on an information plane through a layer,
7 wherein

8 the region of the lens is divided into a plurality of regions including at
9 least both of a first region and a second region by dividing the region of the lens
10 depending on differences in a distance from an optical axis of the lens,
11 the first region being located farther from the optical axis than a position of the
12 second region,

13 the second region being optimized so that the lens has a numerical
14 aperture NA2 to produce a focal point through a second layer on an
15 information plane placed at a distance T2 from the surface of the second layer,
16 and

17 both of the first region and the second region being optimized so that the
18 lens has a numerical aperture NA1 (NA1 is not equal to NA2) to produce a focal
19 point through a first layer on an information plane placed at a distance T1 (T1
20 is not equal to T2) from the surface of the first layer.

155 (New). An optical head apparatus according to claim 154,
comprising:
a collimate lens to change the light beam from the optical source into an
approximately parallel light; and
an optical detector to receive light from both of the information planes
placed at a distance T1 from the surface of the first layer and placed at a
distance T2 from the surface of the second layer, wherein
the compound objective lens receives the approximately parallel light.

156 (New). An optical head apparatus according to claim 154, wherein
the numerical aperture NA1 is larger than the numerical aperture NA2
($NA1 > NA2$) and
the distances T1 and T2 correspond to thicknesses T1 and T2 of the
first and second layers composed of, respectively, first and second information
media included in the optical disk, the thickness T1 being smaller the
thickness T2 ($T1 < T2$).

157 (New). An optical disk apparatus, comprising
(1) an optical head apparatus for performing at least one of recording and
reproduction of pieces of information on and from an optical disk placed to face
the optical head apparatus, comprising
(i) an optical source for radiating a light beam; and

6 (ii) a compound objective lens receiving the light beam and
7 comprising a region to produce a focal point on an information plane through a
8 layer, wherein

9 the region of the lens is divided into a plurality of regions including
10 at least both of a first region and a second region by dividing the region of the
11 lens depending on differences in a distance from an optical axis of the lens,

12 the first region being located farther from the optical axis than a
13 position of the second region,

14 the second region being optimized so that the lens has a numerical
15 aperture NA2 to produce a focal point through a second layer on an
16 information plane placed at a distance T2 from the surface of the second layer,
17 and

18 both of the first region and the second region being optimized so
19 that the lens has a numerical aperture NA1 (NA1 is not equal to NA2) to
20 produce a focal point through a first layer on an information plane
21 placed at a distance T1 (T1 is not equal to T2) from the surface of the
22 first layer;

23 (2) a moving apparatus for moving the optical head apparatus; and

24 (3) a rotating apparatus for rotating the optical disk.

1 158 (New). An optical disk apparatus according to claim 157,
2 comprising: a focus controller to change a distance between the optical disk

3 and the compound objective lens and start focus control when a focus error
4 signal detected from the compound objective lens surpasses a predetermined
5 level so as to perform focus control corresponding to the different distances T1
6 and T2.

1 159 (New). An optical disk apparatus according to claim 157, wherein
2 the numerical aperture NA1 is larger than the numerical aperture NA2
3 (NA1>NA2) and
4 the distances T1 and T2 correspond to thicknesses T1 and T2 of the
5 first and second layers composed of, respectively, first and second information
6 media included in the optical disk, the thickness T1 being smaller the
7 thickness T2 (T1<T2).
